NAT. RES. COUNCIL. COMM. on Marine Ecology --
Rept.

#4

No. 4

LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

PRICE $0.50

# REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

## 1943 - 1944

HARRY S. LADD, CHAIRMAN

Presented at the Annual Meeting of the
Division of Geology and Geography
National Research Council
April 29, 1944

NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue
Washington 25, D. C.

October 1944

(Reprinted January 1951)

NATIONAL RESEARCH COUNCIL

DIVISION OF GEOLOGY AND GEOGRAPHY

WASHINGTON, D. C.

# * REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

April 29, 1944

Appendix K of Annual Report
of the Division for 1943-1944

* (No. 4 in this Series. See page 37
for list of previous reports)

COMMITTEE MEMBERS


Harry S. Ladd, Chairman

| | |
|---|---|
| C. H. Edmondson | Earl H. Myers |
| Gordon Gunter | Roger Revelle |
| Remington Kellogg | F. W. Rolshausen |
| Kenneth E. Lohman | H. C. Stetson |

T. Wayland Vaughan



(First edition, October 1944)
(Reissued without change, January 1951)

CONTENTS


Page

Introduction ..... 1

Bibliography of Paleoecology ..... 1

Ecology of Conodonts by Samuel Ellison ..... 1

Bibliography of Marine Ecology ..... 4

Current Activities ..... 5

Eastern United States ..... 5
Ralph W. Dexter ..... 5
Curtis L. Newcombe ..... 5
Horace G. Richards ..... 6

Middle United States ..... 6
Willis G. Hewatt ..... 6
J. Harlan Johnson ..... 6
S. W. Lowman ..... 6
H. B. Stenzel, F. E. Turner and C. J. Hesse ..... 6

Western United States ..... 11
Barnum Brown and H. E. Vokes ..... 11
Beatrice L. and Thomas A. Burch ..... 12
Wesley R. Coe and Denis L. Fox ..... 12
Denis L. Fox, David M. Updegraff and G. David Novelli .... 12
Frank V. Stevenson ..... 13

Outside the United States ..... 13
C. H. Edmondson ..... 13
J. E. Hoffmeister and H. S. Ladd ..... 14

Recently published papers ..... 14

General ..... 14
Plants ..... 17
Protozoans ..... 18
Sponges ..... 19
Coelenterates ..... 19
Vermes ..... 19
Echinoderms ..... 19
Molluscoids ..... 19
Mollusks ..... 20
Arthropods ..... 21
Vertebrates ..... 21

Biology of the Foraminifera in Relation to Stratigraphy and Petroleum Geology by Earl H. Myers ..... 22

Reefs and other Bioherms by Harry S. Ladd ..... 26

California Fossil Fish Scale Assemblages by Lore Rose David ..... 30

Relations of Salinity and Temperature to Distributions of the Marine Fishes of Texas by Gordon Gunter ..... 32

# REPORT OF THE COMMITTEE ON

# MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

## INTRODUCTION

During the past year the Committee's activities have again been greatly restricted by the fact that most of its members are devoting part or all of their time to war work. No regular meetings have been held but the Chairman has attempted to keep the program alive by correspondence and conferences with Committee members and others. All of the members seem to feel that the framework of the Committee should be held together so that the group will be in a position to function effectively after the war.

The Committee members have carried on a considerable correspondence with biologists and geologists in attempting to obtain information on current activities in marine ecology. Investigations noted in earlier reports have been completed or continued but very few new ecological studies of interest to paleontologists have been reported.

In February 1944, Earl H. Myers, who has contributed papers on the ecology of Foraminifera to earlier reports, was made a member of the Committee.

## BIBLIOGRAPHY OF PALEOECOLOGY

Two additional assignments have been made in the Committee's plan for the preparation of an annotated bibliography of paleoecology. Bruce L. Clark and Arthur S. Campbell will prepare material on the Radiolarians; Allen F. Agnew material on the Ostracodes of the Paleozoic. The first of the eighteen assignments made to date has been completed and is given below. As the Conodonts are a small group of problematical organisms now extinct they have not attracted the attention of many workers, and very little has been written about their probable environment. Mr. Ellison's contribution is not lengthy but it is believed to be reasonably complete. Suggestions, corrections or additions will be welcomed by Mr. Ellison and by the Committee.

## ECOLOGY OF CONODONTS

by

Samuel Ellison
Missouri School of Mines and Metallurgy, Rolla, Mo.

There has been much speculation as to the probable environment of conodonts. The question involves the long standing controversy about the origin of black shale and is further complicated by the fact that conodonts have been found in a great variety of sediments. Inferences as to the conditions under which conodonts lived have been based mainly on lithology and faunal association.

Conodonts are known to occur in limestone, red, gray, green, and black shale, sandy shale, siltstone, sandstone, and conglomerate. This distribution suggests that conodonts were free swimmers (nekton) and possibly pelagic. The abundance of conodonts in black shale may mean that they lived in muddy toxic waters or that they died upon entering such waters.

Since conodonts are composed of calcium phosphate, which is not easily dissolved by sea water, they may accumulate in abyssal deposits, or in deposits of detrital material near shore. Some of the deposits in the upper Devonian of New York are probably of the latter type.

The annotated bibliography that follows is believed to be reasonably complete so far as the ecology of conodonts is concerned. It is possible, however, that some ecological data in the literature have been overlooked.

Bailey, W. F., Micropaleontology and stratigraphy of the lower Pennsylvanian of central Missouri, Jour. Paleontology, vol. 9, pp. 483-502, 1935.

Conodonts are found abundantly in black carbonaceous shales and are considered as living in marine and stagnant brackish waters.

Branson, E. B. and Mehl, M. G., Conodont studies, Univ. Missouri Studies, vol. 8, pp. 1-300, 1934.

Conodonts are rare in limestones but abundant in many shales and sandy shales. Various lithologies are discussed but the probable environment of conodonts is not inferred.

Branson, E. B. and Mehl, M. G., Notes on the ecology of conodonts, Geol. Soc. Amer. Proc. for 1933, p. 362, (abstract), 1934.

Conodonts occur mainly in marine shales of shallow water near-shore origin. Some conodonts may have lived in fresh or brackish waters.

Branson, E. B. and Mehl, M. G., Conodonts from the lower Mississippian of Missouri, Univ. Missouri Studies, vol. 13, no. 4, p. 128, 1938.

The general habitat of conodonts seems to be in waters containing sufficient clay, silt, or sand to prevent limestone formation.

Branson, E. B. and Mehl, M. G., Conodonts from the Keokuk formation, Denison Univ. Bull., vol. 35, pp. 179-189, 1940.

Limestones do not yield large conodont faunas but there may be limited clear water conditions suitable for conodonts.

Bryant, W. L., The Genesee conodonts, Buffalo Soc. Nat. Sci. Bull., vol. 13, no. 2, pp. 1-58, 1921.

The Devonian Genesee sediments containing conodonts are thought to have been accumulated in shallow water near shore. The high concentration of conodonts in some lenses is believed to indicate a detrital origin.

DuBois, E.P., Evidence on the nature of conodonts, Jour. Paleontology, vol. 17, pp. 155-159, 1943.

Conodonts are associated with brachiopods (Orbiculoidea and Lingula), worm trails and burrows, and vertebrate remains such as spines (Lystracanthus), teeth (Cladodus), and scales, (Holmsella). Conodonts occur as pairs or symmetrically arranged groups on slabs of dark fissile shale indicating still waters.

Gunnell, F. H., Conodonts from the Fort Scott limestone of Missouri, Jour. Paleontology, vol. 5, pp. 244-255, 1931.

Conodonts are recorded from shale, sandstone, conglomerate, and limestone. They are considered to be free swimmers.

Gunnell, F. H. and Morey, P., The preparation of conodonts for study, Micropaleontology Bull., vol. 3, pp. 77-78, 1932.

Conodonts occur abundantly in carbonaceous shale, sandstone, and conglomerate, but are rare in limestone and marl.

MacFarlane, J. M., Evolution and distribution of fishes, Noel Printing Company, Philadelphia, Pa., p. 107, 1923.

_____, Fishes, the source of petroleum, Noel Printing Company, Philadelphia, Pa., p. 33, 1923.

_____, Quantity and source of our petroleum supplies, Noel Printing Company, Philadelphia, Pa., pp. 227-238, 1931.

In these three articles the belief is expressed that conodonts were free swimmers living near shore.

Moore, R. C., Environment of Pennsylvanian life in North America, Amer. Assoc. Petroleum Geologists Bull., vol. 13, pp. 459-487, 1929.

Conodonts in black fissile shale may indicate that the organisms were especially adapted to toxic brackish waters or that the organisms died upon entering such waters. The belief is expressed that the black shales were deposited in warm subtropical shallow waters.

Moore, R. C., Stratigraphic classification of the Pennsylvanian rocks of Kansas, Kansas Univ. State Geol. Survey Bull. 22, pp. 1-40, 1936.

Conodonts occur abundantly in dark fissile shales which are thought to have been formed near shore in shallow waters, possibly in lagoons. Conodonts occur in the marine parts of sedimentary cycles.

Reudeman, Rudolf, Paleozoic plankton of North America, Geol. Soc. America, Memoir No. 2, pp. 1-52, 1934.

Black fissile carbonaceous shales with abundant conodonts and graptolites are thought to have formed in the deeper littoral zones in cool stagnant water. Some conodonts, however, may have been deposited in lagoons and some may have lived under conditions much like those in the present Sargasso Sea. In any case, conodonts are so widespread that they should be considered nektonic.

Scott, H. W., Conodont assemblages from the Heath formation, Montana, Jour. Paleontology, vol. 16, pp. 293-300, 1942.

The black muds in which conodont "assemblages" were laid down are interpreted as having accumulated in exceptionally calm and undisturbed waters; otherwise, the conodont groups would have been dispersed.

Smith, John, On the occurrence of conodonts in the Arenig-Llandielo formation of the southern uplands of Scotland, Glasgow Nat. Hist. Soc. Trans., vol. 7, pp. 235-242, 1907.

It is suggested that conodonts are pelagic and that the red and green shales, in which they are found are abyssal deposits.

Smith, R. W. and Whitlatch, G. I., The phosphate resources of Tennessee, Div. of Geology, Dept. of Conservation of Tenn., Bull. 48, p. 308, 1940.

Conodonts found in the Blue Phosphate beds are thought to have been deposited with much organic matter as detritus in shallow, cool, stagnant waters. The waters were probably lagoonal.

## BIBLIOGRAPHY OF MARINE ECOLOGY

As announced in last year's report, the Committee plans to prepare an annotated bibliography dealing with those aspects of the ecology of living marine organisms that are of interest to paleontologists. First assignments have been made, as follows:

Foraminifera ..... Earl H. Myers
Mollusks other than Oysters ..... Willis G. Hewatt
Oysters and Fish ..... Gordon Gunter

Following the war, when the above-mentioned bibliographies are well underway, the Committee plans to begin the preparation of a treatise on marine ecology. This will be an integrated work designed specifically for paleontologists rather than a collection of special papers dealing exclusively with individual groups of organisms or with geographical units.

## CURRENT ACTIVITIES

### EASTERN UNITED STATES

Prof. Ralph W. Dexter of Kent University has completed an article on the "Ecological significance of the disappearance of eel-grass at Cape Ann, Massachusetts" and one describing "The bottom community of Ipswich Bay, Massachusetts".

Director Curtis L. Newcombe reports on investigations being carried on by the Virginia State Fisheries Laboratory as follows:

"The research program of the Virginia Fisheries Laboratory of the College of William and Mary and Commission of Fisheries is centered on problems related to better utilization and management of the marine resources of Tidewater. The blue crab, the oyster, and the ribbed mussel are subjects of current studies.

"The work on the blue crab includes a study of the larval stages by means of rearing experiments and plankton tows. Determining the value of different local waters as brood stock areas for protecting the egg bearing crabs so as to assure an adequate supply of young has involved experimental work on the effect of salinity and temperature on the hatching of eggs and the development and survival of zoea larvae. Knowing the optimum ranges of physical factors for development provides a basis for defining the boundaries of a crab sanctuary. A new fungus parasite has been discovered in the eggs of the crab, and experiments have been conducted to determine its effect on development. The distribution and abundance of the parasite has constituted a further subject of study. With the aid of the National Research Council, steps have been taken to ascertain possible uses for recoverable waste crab meat.

"Oyster investigations deal with surveys of local grounds and the designation of periods and places most suitable for cultural operations. Practical methods are being explored for controlling the oyster drill, the worst enemy of the oyster in Virginia.

"Ecological studies of the ribbed mussel started in 1940 are being continued. In view of the not unlimited supply of this bivalve, rich in provitamin content, cultural studies are emphasized. Various types of artifical culch are being tested to facilitate more rapid production and the possibilities for using small mussels, otherwise valueless, for transplanting as seed are being explored."

Dr. Horace G. Richards of the Academy of Natural Sciences of Philadelphia has continued his study of mollusks from deep wells along the Atlantic coast.

## MIDDLE UNITED STATES

Prof. Willis G. Hewatt of Texas Christian University is continuing his study of the shallow-water faunas of the Gulf of Mexico and expects to spend the summer of 1944 at Grand Isle, Louisiana at the Louisiana State University's marine laboratory.

Prof. J. Harlan Johnson of the Colorado School of Mines is making a study of a reef-like facies in Upper Cretaceous beds in the Terlingua district, Brewster County, Texas. The structures are essentially algal with a few mollusks. A short note was published in the Bulletin of the American Association of Petroleum Geologists for January 1944.

S. W. Lowman of the Shell Company is continuing his work on Gulf cores from an area east of the Mississippi River and has done additional work on a profile extending from the fresh water marshes to an area beyond the continental shelf.

Dr. H. B. Stenzel of the Texas Bureau of Economic Geology, Dr. F. E. Turner and Mr. C. J. Hesse of the Agricultural and Mechanical College of Texas have prepared a paper on the Brackish and Nonmarine Miocene in Southeastern Texas which is ready for publication. A summary of the section on ecology, as received from Doctor Stenzel, is given below:

"Near Burkeville, Newton County, Texas, the Potamides matsoni subsurface zone of southeastern Texas and adjoining Louisiana reaches the surface. Certain features of the beds are indicative of the environmental conditions which prevailed at the time the beds were deposited. One source of information concerning these conditions are the sediments; the second and perhaps more complete source of information is the fauna and flora entombed in these beds. The fauna and flora consists of the following:

Vertebrates:

| | |
|---|---|
| ?Desmostylus | Sea cow, teeth |
| ?Prosynthetoceras | Primitive horned ruminant, horn core and tooth |
| Blastomeryx? | Deer-like animal, toe bone and teeth |
| Camelidae indet. | Camel, bones |
| Merychippus sp. | Horse, jaw and teeth |
| Aphelops sp. | Rhinoceros, leg bone |
| Amblycastor, n. sp. Hesse | Beaver-like animal, skull |
| Aves indet. | Bird, bone |
| Crocodilia indet. | Crocodile, skin plates and teeth |
| Chelonia indet. | Turtle, bones |

Vertebrates - Continued:

| | |
|---|---|
| Reptilian eggs | Reptile, eggs |
| Phyllodus sp. | Wrasse, teeth |
| Ameiurus sp. | Catfish, spines |
| Lepisosteidae indet. | Gar-pike, bones, scales, and skull |
| Plinthicus sp. | Eagle ray, tooth |
| Rhinoptera sp. | Eagle ray, teeth |

Invertebrates:

| | |
|---|---|
| Potamides matsoni Dall<br>Goniobasis n. sp. Stenzel & Turner<br>Pleurocera acutum, n. subsp. Stenzel & Turner | River snails |
| Unio sp. | River mussel |
| Ostrea normalis Dall | Oyster |
| Polydora sp. | Mudworm |
| Rotalia beccarii (Linné) | Foraminifera |

Plants:

Charophyte oogonia

"On first inspection this list appears incongruous, because mutually exclusive habitats are represented by the fossil remains. Snails of the genus Pleurocera are river dwellers which do not inhabit intermittent streams, ponds, or lakes, except as the latter may form part of a stream system; and they are equally unknown in brackish waters. On the other hand, the oyster, which is the most abundant form, requires salt or brackish water. Finally, several of the mammals are land animals, whose habitat is not necessarily close to any large body of water. Such divergent fossil assemblages are not uncommon and need not be contradictory. Much of the mixture of habitats represented by these fossils is due to the fact that the place where a bone or shell is finally embedded in sediment is not necessarily the place where the animal lived. There are numerous possibilities of transportation after death and before final burial in a sediment.

"The oysters occur scattered nearly in the entire exposed section and in definite oyster banks. Such banks are neither extensive nor thick; they are at the best 0.5 foot thick and lenticular; each lentil occupies a few square yards, but the different lentils are in many cases strung up in the same stratigraphic level. The oysters are obviously entombed in the place where they lived, because the oyster beds are preserved as such, and many oysters are found in intact clusters growing on lime nodules and one upon the other. The oysters are mostly young and rarely up to 7 cm. long. The oyster bank fauna is very poor in species but rich in individuals, a rather monotonous assembly. Such assemblies are due to extreme environmental conditions, which allow only those few species to flourish that are well able to stand the extreme conditions. The lack of a diverse accompanying fauna of other pelecypods and gastropods, sea urchins, and the like makes it apparent that the oyster banks grew not in sea water of normal salinity but in brackish water, which

is after all the preferred location of oyster banks. The poor development of the oysters and their beds near Burkeville is indicative of poor growing conditions. Presumably, the oysters lived at the extreme of their tolerance of low salinity.

"Mixed with the fossil oyster shells one finds teeth of rays (Plinthicus and Rhinoptera) and sea cows (Desmostylus sp.). Both kinds of animal had teeth especially adapted to the crushing of shells and both lived off the oysters. In this connection it is interesting to note that the same sea cow genus (Desmostylus) occurs among fossil oyster banks in the Miocene of the west coast of North America. This sea cow genus is extinct today and surviving sea cows do not have teeth adapted to shell crushing. However, rays count also today among the most destructive enemies of the oyster.

"Many of the fossil oyster shells have the tiny loop-shaped bore holes made by the annelid mud worm Polydora. This small animal is also known today and represents a real danger to present-day oyster beds. Oysters living today along the Atlantic and Gulf Coasts of North America are infested by the Polydora ciliata (Johnston) which has been studied recently by G. R. Lunz. 1/ This biologist reports:

'This particular pest is a small annelid which causes a 'mud blister' in the oyster. This is a small, irregular, often pear-shaped, blister of mud, formed on the surface of the inside of the valve. The oyster covers this daub of mud with a layer of nacre. Within the blister one finds the annelid, which has access to the outside through two tunnels opening along the edge of the shell. The worm has been identified by Dr. Olga Hartman as Polydora ciliata (Johnston). Although Polydora is well known, its occurrence in such abundance as to become an oyster pest seems as yet unreported in the U. S.'

'The worm upsets the normal life of the oyster by restricting its living space and generally weakening it. Infested oysters, although not unfit for food, are not readily salable because of their unsightly appearance.'

'I have had these worms and the blister they cause under observation since 1935. Indications are that the worms were prevalent in South Carolina even in pre-colonial days. An examination of numerous samples of South Carolina oysters shows that approximately 30 per cent of the oysters are infested with Polydora.'

"According to Lunz2/Polydora is more prevalent in intertidal waters of

---

1/ Lunz, G.R., The annelid worm Polydora as an oyster pest: Science n.s., vol. 92, p. 310, 1940.

2/ Lunz, G.R., Jr., Polydora, a pest in South Carolina oysters: Elisha Mitchell Sci. Soc. Jour., vol. 57; no. 2, pp. 273-283, 1941.

low salinity and prefers its oysters on a muddy or soft bottom rather than on a firm or hard bottom in South Carolina. Present-day conditions on the coast of the South Carolina coastal plain are presumably similar to those of Miocene time on the coast of the Texas coastal plain.

"There are also among the fossils an upper right pharyngeal and a few small rounded teeth which seem to belong to a fish of the family Labridae and the genus Phyllodus. This family, the wrasses, are marine and chiefly tropical in distribution today.

"The foraminifer Rotalia beccarii (Linné) has today its optimum development in shallow, brackish coastal waters.3/ For instance, the shore sands of San Francisco Bay abound in specimens of this foraminifer; but it has not been found in samples from the littoral zone of the open-ocean coast of the Pacific. Collections from other bays of western North America include this species. The same may be said for the coasts of Louisiana and Texas. In the brackish Maracaibo lake in Venezuela lives an association of foraminifers like that of San Francisco Bay with abundant Rotalia beccarii (Linné). There is no reason to assume that the habits of this foraminifer have changed since Miocene time.

"The fossil river snails (Goniobasis and Pleurocera) are not found in the oyster banks but occur together with the river mussels (Unio) in somewhat higher parts of the section in two localities. Representatives of the same genera are living today. These modern representatives live in fresh river waters and are nearly always intolerant of brackish water.

"In many present-day rivers, the original brownish horny covering membrane of the shell or the so-called periostracum is missing over the tip of the spire of snails and over the umbones of all adult mussels. These places are deeply etched and pitted in such cases. This condition is due to the acid reaction of the river water which attacks and corrodes the calcium carbonate of the shells. The corrosion is usually localized in these places because they are the oldest and most exposed portions of the shell. The tip of the spire in every specimen of the two species of fossil river snails from Burkeville is corroded and fractured. The fossil river mussels (Unio sp.) from Burkeville are damaged even to a greater extent. Part of this damage is purely mechanical, that is, due to breakage during transportation. However, corrosion is certainly also responsible for the lack of the spire tip in the snails and the lack of the umbonal points in the mussels in the Miocene of Burkeville. These observations corroborate what is known of the habitat of such river snails and mussels.

"Breakage among these fossils is all too obvious, and it seems an inescapable conclusion that these fossils were transported for a considerable

---

3/Schenck, H. G., Applied paleontology: Bull. Amer. Assoc. Petr. Geol., vol. 24, p. 1762 and fig. 4, 1940.
Macfadyen, W. A., Post-glacial Foraminifera from the English Fenlands: Geol. Mag., vol. 75, no. 891, pp. 412, 415, 1938.

distance before they were embedded in Miocene time in the clay which now encloses them. In the case of a river this transportation would probably be in a downstream direction and the shells may have finally reached a resting place in lime-rich muds near the mouth of the river. Indicative of fresh water rivers are also the remains of Lepisosteidae, the gar-pikes, and Ameiurus sp., a catfish. The former are represented by scales and incomplete skull bones, the latter by bony fin-spines.

"The several fossil land mammals, horse, rhinoceros, deer, horned ruminant, and camel, are obviously buried in a place where they did not live. These fossils were probably washed in from upstream as floating and disintegrating carcasses. On the other hand, it is possible that the beaver lived very nearly in the same environment as the fossil river snails and mussels.

"As a whole, the sedimentary environment of the strata near Burkeville, as it is indicated by the sediments and fossils, fluctuated from flowing fresh-water streams to somewhat brackish coastal waters. The fluctuations from one to the other did not involve great changes in physical conditions nor did the geographic distribution of land and sea have to change much to produce all the various sedimentary environments represented in the beds near Burkeville. Most plausibly the locale was near the mouth of a river system emptying into a brackish water lagoon along the Miocene coast of Texas.

"Environmental Distribution of Fauna

Brackish water -- oyster bank fauna

| | |
|---|---|
| Ostrea normalis Dall | oyster; chief food source |
| Rhinoptera sp. | ray; oyster enemy |
| Plinthious sp. | ray, oyster enemy |
| Desmostylus sp. | sea cow, oyster enemy |
| Polydora sp. | mudworm; parasite of oyster |
| Phyllodus sp. | wrasse |
| (Potamides matsoni Dall | snail) |
| (Crocodilia indet. | crocodiles or alligators) |
| Rotalia beccarii (Linné) | foraminifer |

Fresh water -- river fauna

| | |
|---|---|
| Lepisosteidae indet. | gar-pikes |
| Ameiurus sp. | catfish |
| Amblycastor, n.sp. Hesse | beaver-like rodent |
| (Potamides matsoni Dall | snail) |
| Goniobasis n.sp. Stenzel & Turner | river snail |
| Pleurocera acutum n. subsp. Stenzel & Turner | river snail |
| Unio sp. | river mussel |
| (Chelonia indet. | turtles) |
| (Crocodilia indet. | crocodiles or alligators) |

Firm land

| | |
|---|---|
| Aphelops sp. | rhinoceros |
| Merychippus sp. | horses |
| Camelidae indet. | camels |
| Blastomeryx? | deer-like ruminant |
| Prosynthetoceras? | horned ruminant |
| (Chelonia indet. | turtles) |

Note: Parentheses indicate uncertainty in assignment to a definite environment."

## WESTERN UNITED STATES

Drs. Barnum Brown and H. E. Vokes of the American Museum of Natural History have completed a report on some unusual fossil imprints collected by Doctor Brown near Billings, Montana (imprints of this type were previously described by Vokes, Amer. Jour. Sci., vol. 239, pp. 451-453, 1941; see also Rept. Comm. Mar. Ecol. 1941-42, p. 28). The imprints appear on two slabs measuring 16 by 53 and 21 by 74 inches. In addition comparisons are made with photographs of specimens found near Cody, Wyoming, by W. G. Pierce and a specimen from Winnett, Montana.

Messrs. Vokes and Brown state:

"Each of the large slabs shows 13 imprints, arranged in a series of 8 prints, plus parts of one or more additional series. Examination shows that while the prints were predominantly radially symmetrical, this radial symmetry had been super-imposed upon what must have been a primary bilateral symmetry in the animal which made them. The chance discovery, in the collections of the American Museum of Natural History, of a specimen of a squid from the Solenhofen Jurassic in which the tentacular ring is preserved showing exactly the same 8-pointed type of radial arrangement of the tentacles, led to further investigation of that group as possible sources for the prints. Drew has shown that the modern Loligo pealii, when in the act of laying her eggs, often grasps the egg mass within the tentacular ring, and holding them close together, 'bounces' along on the sea-bottom until she locates a stone, or other hard substance upon which to stick the egg mass. All of which is suggestive only, but it would serve to explain the fact that the prints tend to occur in series.

"All of this has led us to suggest.....that the prints may have been made by some type of dibranchiate cephalopod, possibly one in which the tentacles were armed with chitonous hooks, similar to those known to have occurred in the belemnites as well as in a few modern types.....

"In the area where the two large slabs were secured, and possibly in the other known localities, although we have no data concerning these areas, the imprint-bearing layer was immediately overlain by a thin deposit of bentonitic clay. It is probable that the tracks were preserved by being

immediately buried before they could be destroyed by wave or current action. This factor may serve to explain the fact that they are only known from the upper part of the Mowry shale, the principal volcanic zone in the midcontinent Cretaceous. They seem to have a definite stratigraphic value.

Under the editorship of Beatrice L. and Thomas A. Burch the Conchological Club of Southern California recently started to make a survey of western North American mollusks. Material collected by the club from Alaska to Mexico will be recorded in a series of papers to appear in the Club's mimeographed minutes. The data will include the synonomy, depth of occurrence, type of substrate, distribution in Pleistocene and Recent deposits, etc. The first paper in the proposed series deals with the Tellinidae and appeared in the minutes for July 1943.

In the minutes for March 1944 the Club under the editorship of John Q. Burch began the publication of a Check List of west North American mollusks from San Diego, California to Alaska. Dr. Myra Keen of Stanford University is contributing to the prodrome of this check list.

Wesley R. Coe and Denis L. Fox of the Scripps Institution of Oceanography have prepared a third report on the biology of the California sea-mussel (Mytilus californianus). It describes environmental conditions and rate of growth during four successive years. The authors summarize their findings, as follows: "For each of the four years a rather close correlation has been found between monthly growth rate and the temperature gradient with the exception of August, the month with the highest temperature, when there has been a decreased rate in each of the four years. The most rapid increase in size takes place at temperatures from 17 to 20° C., although growth continues at 14° or lower.

"A positive correlation between growth rate and abundance of dinoflagellates has been found, with a few monthly exceptions, during the entire period. During the last two years there was a 422 per cent increase in the available phytoplankton as compared with the first two years. This was accompanied by an average increase of only 42 per cent in the growth of the mussels. No direct correlations were found between the abundance of either diatoms or bacteria and the rate of growth, although both these organisms supply portions of the mussels' nutrition. Correlations between abundance of dinoflagellates and growth rate of mussels are regarded as parallel reflections of favorable environmental factors."

Denis L. Fox, David M. Updegraff and G. David Novelli of the Scripps Institution of Oceanography of the University of California, have made a study of carotenoid pigments in the ocean floor. The authors report:

"This study, a report of which is yet unpublished, represents an extension of investigations which have been in progress at La Jolla during several years. While the oxygenated, so-called xanthophyllic, carotenoids preponderate considerably over the hydrocarbon or carotene type in marine

plant life, also in the great majority of marine animals investigated and in suspended marine detritus, a striking reversal in ratio has been encountered in mud cores taken from the ocean floor off the coast of southern California and in the Gulf of California. Top layers of mud yield carotenes in quantities more nearly equal to amounts of xanthophylls, while deeper layers of sediment, representing successively greater ages, show preponderances of carotenes over xanthophylls in the order of from 2:1 to nearly 9:1. Carotenoids in concentrations of ca. 0.26 mg. per 100 g. dry mud have been recovered from oceanic deposits, off the southern coast of California, ranging in estimated age from 15 to 2500 years. Gulf mud of about 6000 years standing has yielded carotenoids in concentrations close to 6 mg. per 100 g. dry material.

"Beta-carotene and closely similar isomers were the commonest hydrocarbon polyenes encountered, with alpha-carotene and isomers similar to it in secondary prominence. Rare carotenes associated with certain microorganisms were frequently encountered. Among the xanthophylls, compounds similar to zeaxanthin predominated, with lutein or luteinisomers in secondary abundance; others resembling fucoxanthin, petaloxanthin and sulcatoxanthin were observed frequently. Glycymerin and astacene were suspected in a few cases.

"The rather arresting fact of these ordinarily labile pigments having been preserved over centuries of time is explained by the prevailing conditions of highly reducing environments, low temperatures and complete darkness, in the buried mud strata.

"Several agencies have been provisionally suggested to account for the selective accumulation of the hydrocarbon type over the alcoholic class of carotenoids in marine sediments: (1) greater tendency and rate of autoxidation of xanthophylls, where oxygen is available; (2) selective assimilation of xanthophylls and fecal rejection of carotenes by most marine animals; (3) possible reduction of xanthophylls to hydrocarbon types by certain marine microorganisms in anaerobic environments.

"Some emphasis is directed toward the bearing of these investigations upon problems related to biogenic origins of petroleum."

Frank V. Stevenson, a graduate student at the University of Chicago, is making a detailed study of the fauna of the Devonian sediments of New Mexico attempting to interpret the relationship of the fossils to special sedimentological features in the section.

## OUTSIDE THE UNITED STATES

Dr. C. H. Edmondson has revised his "Reef and Shore Fauna of Hawaii" for republication by the Bishop Museum.

Dr. J. E. Hoffmeister of the University of Rochester and H. S. Ladd have completed the third and last paper in a series of three dealing with the origin of coral reefs. The paper, entitled "The Antecedent Platform Theory", describes ways in which coral reefs may be formed, examples being cited from Fiji and Tonga; the paper will appear in The Journal of Geology.

## RECENTLY PUBLISHED PAPERS

### GENERAL

Brady, F., The Distribution of the fauna of some intertidal sands and muds on the Northumberland coast, Jour. Anim. Ecol., vol. 12, pp. 27-41, 1943.

Colliver, F. S., Notes on the mineral replacement of fossils, Victorian Nat., vol. 58, pp. 135-138, 1942.

Cooper, Byron N., Lower Middle Ordovician along Clinch Mountain in Virginia and Tennessee, (Abst.), Bull. Geol. Soc. Amer., vol. 54, p. 1824, 1943.

Cooper, Byron N. and Prouty, Chilton E., Stratigraphy of the lower middle Ordovician of Tazewell County, Virginia, Bull. Geol. Soc. Amer., vol. 54, pp. 819-886, 1943.

Cowles, R. P. and Brambel, C. E., Plankton organisms where fresh and salt waters meet, (Abst.) Anat. Rec., vol. 84, p. 504, 1942.

Deacon, G.E.R., The Sargasso Sea, Geog. Jour., vol. 99, pp. 16-28, 1942.

Eisenbise, M. E., A study of plankton with reference to contributing animals, Jour. Ent. and Zool., vol. 35, p. 1, 1943.

Grossman, William L., Stratigraphy of the Genessee Group of New York, Bull. Geol. Soc. Amer., vol. 55, pp. 41-76, 1944.

Hamm, H. J., A study of the role and importance of bacteria in ocean beaches at Beaufort, North Carolina, Jour. Elisha Mitchell Sci. Soc., vol. 58, pp. 128-129, 1943.

Hedberg, Hollis D. and Pyre, Augustin, Stratigraphy of northeastern Anzoategui, Venezuela, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 1-28, 1944.

Imlay, Ralph W., Jurassic formations of Gulf Region, Bull. Amer. Assoc. Petrol. Geol., vol. 27, pp. 1407-1533, 1943.

Johnson, J. Harlan, Algal reefs in Cretaceous Austin chalk of Terlingua district, Brewster County, Texas, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 123-124, 1944.

King, Robert E., Dunbar, Carl O., Cloud, Preston E. Jr., and Miller, A. K., Geology and paleontology of the Permian area northwest of Las Delicias, Southwestern Coahuila, Mexico, Geol. Soc. Amer., Spl. Paper 52, pp. 1-172, 1944.

Lochman, Christina and Duncan, Donald, Early Upper Cambrian faunas of central Montana, Geol. Soc. Amer., Spl. Paper 54, pp. 1-181, 1944.

Lozo, Frank E. Jr., Aptian Lower Cretaceous Foraminifera and Ostracoda from San Juan Raya, Puebla, Mexico, (abst.) Bull. Geol. Soc. Amer. vol. 54, p. 1831, 1943.

Lozo, Frank E. Jr., Bearing of Foraminifera and Ostracoda on Lower Cretaceous Fredericksburg-Washita boundary of North Texas, Bull. Amer. Assoc. Petrol. Geol. vol. 27, pp. 1060-1080, 1943.

MacClintock, Paul, Marine topography of the Cape May formation, Jour. Geol., vol. 51, pp. 458-472, 1943.

Mare, Molly F., A study of a marine benthic community with special reference to the micro-organisms, Jour. Marine Biol. Assoc., vol. 25, pp. 517-554, 1942.

Mears, Eliot G., The Callao Painter, Sci. Monthly, vol. 57, pp. 331-336, 1943.

Describes a recurrent summer condition on the west coast of South America when large amounts of $H_2S$ emitted from the sea injure life of the coast.

Paul, M. P., Studies on the growth and breeding of certain sedentary organisms in Madras Harbour, Proc. Indian Acad. Sci., Sect. B, vol. 15, pp. 1-42, 1942.

Price, W. Armstrong and Gunter, Gordon, Certain recent geological and biological changes in South Texas, etc., Trans. Texas. Acad. Sci., vol. 26, pp. 138-156, 1943.

Read, William F., Environmental significance of a small deposit in the Texas Permian, Jour. Geol., vol. 51, pp. 473-487, 1943.

Riley, G. A., Plankton Studies, V, Regional summary, Jour. Mar. Research, vol. 4, pp. 107-111, 1941.

Sayles, Robert W. and Knox, Arthur S., Fossiliferous tills and intertill beds of Cape Cod, Massachusetts, Bull. Geol. Soc. Amer., vol. 54, pp. 1569-1612, 1943.

Taliaferro, Nicholas L., Cretaceous and Paleocene of Santa Lucia Range, California, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 449-521, 1944.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Thomas, Emil Paul, The Claiborne, Mississippi State Geological Survey, Bull. 48, pp. 1-96; 26 text figs.; profiles A-E; pls. 1, 2; 1942.

McGlothlin, Tom, General geology of Mississippi, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 55, 56; figs. 3, 4, 14, 15; Jan. 1944.

Cook, C. Wythe, Geology of the Coastal Plain of Georgia, U. S. Geol. Survey, Bull. 941, pp. 40, 53-61; February 1944.

Although none of the above three papers are concerned directly with ecology, the detailed description of the conditions of sedimentation, particularly in the Claiborne by Thomas, gives significant data on the environment of the Claiborne faunas. The relative importance of time and ecology in accounting for the difference in the composition of the faunas of Mississippi and those of the standard section in western Alabama is still a debated question.

Thomas's section includes the following units:

Cockfield formation
Wautubbee formation
    Gordon Creek shale member
    Potterchitto member
    Archusa marl member
Kosciusko formation
Zilpha shale
Winona greensand
Tallahatta formation
    Neshoba sand member
    Basic claystone member

All of the faunas lived in comparatively shallow in-shore seas. The turbidity of the water, the nature of the material brought in, the strength of the currents and the proximity of the shore line along which the biota lived are variable factors. The fauna of the brittle Tallahatta claystone and of the fine grained thin-bedded sediments into which it grades laterally, includes little more than molds of large thin shelled lucinoid molluscs, many of them still paired. Heavier shells would have been buried in the soft oozey bottom and sluggish current action may have cut down the food supply. The water was not deep but it was quiet and removed from areas of active erosion. In the succeeding Winona, the currents were stronger, the sand and the shells, relatively coarse. Ostrea lisbonensis, Protoscutella mississippiensis, crabs and sharks flourished along a shore that extended from western Alabama to eastern Texas. The same fauna persisted during early Zilpha time but no marine

fauna has been recorded in either the later Zilpha shale or in the overlying Kosciusko sand. Ostrea sellaeformis "reefs" range in the Wautubbee from the Archusa marl through the Potterchitto into the Gordon Creek shale member. They indicate bottoms at least sufficiently hard and water sufficiently clear to permit the larval forms to adhere to the clutch and to develop. The later Gordon Creek shale is probably of deltaic origin. Laterally, the "reefs" have been traced eastward to the Savannah River and occur in isolated outcrops as far west as East Texas. Fairly uniform ecologic conditions must be postulated along their line of strike. A rich flora but no fauna has been collected from the Cockfield sands, clays and shales which closed the Claiborne sedimentation. (Julia Gardner)

Warthin, Aldred S., Jr. and Cooper, G. Arthur, Traverse rocks of Thunder Bay region, Michigan, Bull. Amer. Assoc. Petrol. Geol.,vol. 27, pp. 571-595, 1943.

Woodring, W. P., Bramlette, M. N. and Lohman, K. E., Stratigraphy and paleontology of Santa Maria district, California, Bull. Amer. Assoc. Petrol. Geol., vol. 27, pp. 1335-1360, 1943.

Williams, James Steele, Stratigraphy and fauna of the Louisiana limestone of Missouri, U. S. Geol. Surv. Prof. Paper 203, 1943.

Wood, Alan, "Algal dust", and the finer-grained varieties of Carboniferous limestone, Geol. Mag., vol. 78, pp. 192-200, 1941.

Zenkewich, L., The influence of Caspian and Black Sea waters of different concentrations upon some common Black Sea invertebrates, Part 1, Survival and body weight changes, Zoologicheskii. Zhurmal, (U.S.S.R.), vol. 17, pp. 845-876, 1938. (Author's summary Biol. Absts. vol. 17, p. 1828, 1943).

## PLANTS

Allen, W. E., Depth relationships of plankton diatoms in sea water, Jour. Marine Res., vol. 4, pp. 107-111, 1941.

Bharucha, F. R. and Navalkar, B. S., Studies in the ecology of mangroves, III, The chloride-content of sea-water, soil-solution and the leaf cell-sap of mangroves, Jour. Univ. Bombay, vol. 10, pp. 97-106, 1942.

Blomquist, H. L. and Pyron, J. F., Drifting "seaweed" at Beaufort, North Carolina, Amer. Jour. Bot., vol. 30, pp. 28-32, 1943.

Seaweed on beach at Beaufort following a hurricane consisted of tropical and subtropical forms, some normal to Gulf Stream, some from Bahamas and some from submerged continental "reefs".

Davis, John H., Natural features of southern Florida, Fla. Geol. Surv., Geol. Bull. 25, 1943.

Dunn, Mary D., The marine algal associations of St. Andrews district, I, The dominant associations of the spray and littoral regions, Trans. Bot. Soc. Edinburgh, vol. 33, pp. 83-93, 1944.

Associations of plants in the zone of the spray above high tide mark, the region between tide-marks and the region below low tide are described.

Fenton, Carroll L., Pre-Cambrian and early Paleozoic algae. Amer. Midland Naturalist, vol. 30, pp. 83-111, 1943.

In this paper Dr. Fenton reviews the occurrences of fossil cells, filaments, films, and impressions attributed to algae and concludes that many are correctly so allocated, but cites several examples that are more probably of animal or other origin. He devotes a number of pages to the discussion of stromatolites and in answer to the question, Are they organic?, states that "the inorganic origin of stromatolites is a hypothesis without present support", and that "analogy with modern algal deposits, especially those of the cyanophytes, indicates that each stromatolite is the product of several species or even genera of algae that lived in communal, if not symbiotic, association". The references cited constitute a valuable key to the literature on fossil algae. (Roland W. Brown).

Kryshtofovich, A., The mode of preservation of plant fossils and its bearing upon the problem of coal formation, Amer. Jour. Sci., vol. 242, pp. 57-73, 1944.

Wells, John W., Pseudo-algal nodules in the Greenfield dolomite (Upper Silurian of Ohio), Ohio Jour. Sci., vol. 42, pp. 53-59, 1942.

## PROTOZOANS

Beck, R. Stanley, Eocene Foraminifera from Cowlitz River, Lewis County, Washington, Jour. Paleontology, vol. 17, pp. 584-614, 1943.

Campbell, Arthur S. and Clark, Bruce L., Miocene radiolarian faunas from southern California, Geol. Soc. Amer., Spl. Paper 51, pp. 1-76, 1944.

Curran, John F., Eocene stratigraphy of Chico Martinez Creek area, Kern County, Calif., Bull. Amer. Assoc. Petrol. Geol., vol. 27, pp. 1361-1386, 1943.

Myers, Earl H., Life activities of Foraminifera in relation to marine ecology, Proc. Amer. Phil. Soc., vol. 86, pp. 439-458, 1943.

Nicol, David, New West American species of the foraminiferal genus Elphidium, Jour. Paleontology, vol. 18, pp. 172-185, 1944.

SPONGES

Okulitch, Vladimir, North American Pleospongia, Geol. Soc. Amer., Spl. Paper 48, 1943.

COELENTERATES

Bentson, Herdis, Eocene (Capay) corals from California, Jour. Paleontology, vol. 17, pp. 289-297, 1943.

Durham, J. Wyatt, Reef corals from the California middle Eocene, Calif. Acad. Sci. Proc., 4 ser., vol. 23, pp. 503-510, 1942.

Faul, Henry, Growth-rate of a Devonian reef-coral (Prismatophyllum), Amer. Jour. Sci., vol. 241, pp. 579-582, 1943.

Monsour, Edward, Fossil Corals of the genus Turbinolia from the Gulf Coast, Jour. Paleontology, vol. 18, pp. 109-118, 1944.

Smith, F. G. Walton, Littoral fauna of the Miami area, I. The Madreporaria, Fla. Acad. Sci. vol. 6, pp. 41-48, 1943.

VERMES

Howell, B. F., Burrows of Foralites from the Cambrian of the Champlain Valley, (Abst.), Bull. Geol. Soc. Amer., vol. 54, p. 1831, 1943.

ECHINODERMS

Hawkins, H. L., Evolution and habit among the Echinoidea, Proc. Geol. Soc. London, No. 1393, pp. 50-51, 1943.

Peck, Raymond E., Lower Cretaceous crinoids from Texas, Jour. Paleontology, vol. 17, pp. 451-475, 1943.

MOLLUSCOIDS

Condra, G. E. and Elias, M. K., Study and revision of Archimedes (Hall), Geol. Soc. Amer., Spl. paper 53, pp. 1-243, 1944.

## MOLLUSKS

Bequaert, Joseph C. and Clench, W. J., Additions to the rheophilous mollusk fauna of the Congo Estuary, Bull. Mus. Comp. Zool., vol. 88, No. 1, pp. 1-13, 1941.

A fresh water snail (Potadoma agglutinans n. sp.) living in narrow rock crevices in swift currents cements itself to nearby objects and as a result adult shells are much deformed.

Dexter, Ralph W., Observations on the local movements of Littorina litoria (L.) and Thais lapillus (L.) Nautilus, vol. 57, pp. 6-8, 1943.

Dexter, Ralph W., A source of misleading molluscan records, Nautilus, vol. 57, pp. 67-68, 1943.

Dexter, Ralph W., Shell heaps of the Herring Gull, Nautilus, vol. 57, p. 69, 1943.

Flower, Rousseau H., Tissue remnants in the phragmocone of Rayonnoceras, Bull. Amer. Paleontology, No. 109, pp. 1-12, 1943.

Gifford, D. S. and Gifford, E. W., California Olivellas, Nautilus, vol. 57, pp. 73-80, 1944.

Ingram, William Marcus, Comments on F. A. Schilder's "Cypraeacea from Hawaii" and Schilder and Schilder's "Prodrome of a monograph on living Cypraeidae", Nautilus, vol. 57, pp. 22-27, 1943.

Keen, A. Myra, Catalogue and revision of the gastropod subfamily Typhinae, Jour. Paleontology, vol. 18, pp. 50-72, 1944.

Medcaf, J. C. and Needler, A. W. H., The influence of temperature and salinity on the condition of oysters (Ostrea virginica), Jour. Fish Res. Bd. Canada, vol. 5, pp. 253-257, 1941.

Nicol, David, Observations on Pseudomonotis, a late Paleozoic pelecypod, Nautilus, vol. 57, pp. 90-93, 1944.

Rehder, Harold A., Corrections and ecological notes on some recently described Florida marine shells, Nautilus, vol. 57, pp. 32-33, 1943.

Reinhart, Phillip W., Mesozoic and Cenozoic Arcidae from the Pacific slope of North America, Geol. Soc. Amer., Spl. Paper 47, pp. 1-117, 1943.

Richey, K. A., A marine invertebrate fauna from the Orinda, California, formation, Univ. Calif. Pub., Bull. Dept. Geol. Sci., vol. 27, pp. 25-36, 1943.

Russell, Henry D., The Recent mollusks of the family Neritidae of the western Atlantic, Bull. Mus. Comp. Zool., vol. 88, No. 4, pp. 345-404, 1941.

Schechter, Victor, Tolerance of the snail Thais floridana to waters of low salinity, Ecol., vol. 24, pp. 493-499, 1943.

ARTHROPODS

Caster, Kenneth E., Limuloid trails from the Upper Triassic (Chinle) of the Petrified Forest National Monument, Arizona, Amer. Jour. Sci., vol. 242, pp. 74-84, 1944.

Cooper, Chalmer L., Ostracode moulting in a species of Ectodemites, (abst.) Bull. Geol. Soc. Amer., vol. 54, p. 1829, 1943.

Emery, K. O., Beach markings made by sand hoppers, Jour. Sed. Petrology, vol. 14, pp. 26-28, 1944.

Kellett, Betty, Permian ostracodes, Jour. Paleontology, vol. 17, pp. 615-628, 1943.

Sexton, E. W., The relation of Gammarus paddachi Sexton to some other species of Gammarus occurring in fresh, estuarine and marine waters, Jour. Marine Biol. Assoc., vol. 25, pp. 575-606, 1942.

VERTEBRATES

Wells, John W., Middle Devonian bone beds of Ohio, Bull. Geol. Soc. Amer., vol. 55, pp. 273-302, 1944.

# BIOLOGY OF THE FORAMINIFERA IN RELATION TO STRATIGRAPHY AND PETROLEUM GEOLOGY

by

Earl H. Myers

The rapid draining of proven oil reserves and the anticipated increase in demand for petroleum products following the present emergency explains in part the recent expansion in laboratory and field facilities for the exploration of favorable areas and the testing of deeper formations in apparently exhausted fields.4/

In the search for petroleum, geophysical methods have proven valuable in obtaining structural data in advance of drilling operations; however, the search for oil traps with only slight regard for data on stratigraphy, sedimentation, or possible source rock is an inefficient short-term policy. The interpretation of geophysical data is dependent upon sound geology, and stratigraphy upon our knowledge of sedimentation.5/ In making geological correlations the Foraminifera are a useful guide to most geological systems and formations, and to the recognition of the changing facies within a formation or member. They also serve as guides to the environment that produced these facies. Of late much attention has been given to the possible recognition of source rocks, and should this approach prove fruitful the Foraminifera will serve as guides to the conditions that produced these sediments, and the possible extent of the deposits, since most species of Foraminifera are limited by a narrow range in ecological conditions.

Knowledge of the ecological conditions that prevailed at the time a given sediment was deposited and those factors which limit the geographical distribution of species are essential to a comprehensive use of the Foraminifera as guide fossils. Unfortunately, our total knowledge of those factors which limit the success of the Foraminifera, based upon observations of living organisms, could be summarized in a few brief paragraphs.

In any attempt to appreciate the significance of the tests found in samples from older marine sediments, one must consider such questions as, what was the probable geographic and bathymetric range of the species during a given interval? Were these species limited to a type of substratum that was nowhere extensive? Were they capable of being transported considerable distances by current action or other agencies? What were the possible limits of tolerance of these or related species to temperature, depth, salinity, food and other ecological conditions? What relationship existed between the species

---

4/ Pratt, Wallace E., Our petroleum resources, Amer. Sci., vol. 32, no. 2, April 1944.

5/ Levorsen, A. I., Smithsonian Institution Annual Report, 1942.

that make up an assemblage and the population that actually inhabited the area at the time sediments were deposited?

In the samples I have studied, there were seldom more than twenty species each of which comprised as much as one percent of the total population, and the majority of all species failed to show evidence of having originated in the area, since the tests were devoid of protoplasm. Where samples of surface sediments are obtainable, one may readily distinguish those species which actually inhabit the region from those that were introduced, by treating the sample first with formalin and then acidified alcohol. Following decalcification of the tests, the Foraminifera that were alive may be counted and identified from the protoplasmic casts of the chambers and canal system where present.6/ When samples contain an unusual number of individuals of more than twenty species, it is well to study the configuration of the bottom if possible, and the texture of the sediments. Coarse sediments suggest much sorting and the probable mixing of populations, while muds rich in organic matter, especially where fragments of larger algae occur at depths below the photic zone, make it evident that much of the material was derived from adjacent coastal areas or reefs. Wherever currents exist smaller tests are readily transported for great distances.

In making geologic correlations species having a wide geographic and a limited stratigraphic distribution are of greatest value irrespective of their relative abundance in the samples. In attempting to recapitulate the ecological conditions that prevailed at any given time, the dominant species as to the numbers of individuals are of greatest value since they more probably originated at the surface of the sediment in question. If a taxonomist working on recent Foraminifera fails to indicate the dominant species in his samples he renders his paper virtually useless to one who would attempt to chart the probable vertical and geographic distribution of species. Data concerning hydrographic and other conditions should also be included with check lists of Recent species, since these data are often difficult or impossible to obtain outside of the immediate area.

Unfortunately only a few attempts have been made to study foraminiferal populations in the different facies encountered in passing from the shore to beyond the continental shelf. Data of this nature taken in different latitudes, would be invaluable and much of this material could be obtained during the surveys of the island areas of the Pacific and the Gulf of Mexico that have been proposed as post-war projects. Should these projects be carried through, trained ecologists interested in the Foraminifera should not only have an opportunity to study the samples, but should be present when they are taken.

---

6/ Myers, E. H., Rate at which Foraminifera are contributed to marine sediments, Jour. Sed. Petrology, vol. 12, no. 2, pp. 92-95, 1942.

At even moderate depths the majority of Foraminifera have small tests and show no evidence of dimorphism suggesting that they only reproduce asexually. Where dimorphic species occur, the density of the population must have been sufficient to assure the fertilization of gametes from different individuals. This does not mean that the gametes are released in the water, and left to chance meeting, for it has been demonstrated in certain species that an individual about to produce gametes liberates a chemical activator or hormone that activates other megalospheric individuals in the immediate vicinity.

Much is yet to be learned concerning life cycles and the significance of polymorphism, although it is only necessary to study a reasonable number of specimens of Sorites or Amphisourous to observe that megalospheric individuals may at times reproduce asexually, and for more than a half century it has been accepted that the microspheric generation is sexually produced. Trimorphism of this nature is, however, the rare exception.

Interesting speculations have been made upon the way in which certain types of tests have come into existence, but unfortunately the majority of these speculations have been based upon an inadequate biological background. The nuclei of the Foraminifera divide mitotically and there is no reason to believe that specific characters are less well established through genes or hereditary determiners in the Foraminifera than in other groups including man. Associated groups of individuals of the same species are the result of fusion prior to sexual reproduction, while compound tests having two or more apertural or terminal chambers are the result of the union of two or more juveniles before the protoplasm has become appreciably differentiated from the parent protoplasm, when two or more usually megalospheric proloculi and as many nuclei will be found. In other instances they are the result of a pseudo-type of budding caused by an injury to one or more chambers and the number of nuclei in these tests is normal for the species. The inclusion of the tests of juvenile individuals of the same species within a larger test may have resulted from reproductive activities. When these or the tests of other species are actually incorporated into the walls of a non-arenaceous species, their presence may be explained in the same manner that one would explain the inclusion of a rock crystal or bit of coral that had become attached to the test. With the addition of subsequent chambers these bodies first become encased in protoplasm and later covered by the developing chamber or chambers. When describing hypothetical conditions in the Foraminifera it is well to avoid the use of technical terms such as plastogamy, cytogamy, and syzygy since they only serve to confuse unless the meaning is otherwise clear.

Temperature is an important factor in limiting the bathymetric and geographic distribution of species, and is the factor usually stressed since it is so easily measured. When food is abundant, growth and reproduction will take place in the Foraminifera irrespective of a wide range in temperature. Nutrient salts are essential to marine plants, and sunlight to photosynthesis.

The sunlight warms the water, but long before the temperature has risen appreciably food becomes abundant and the Foraminifera become active. That Foraminifera depend upon specific food organisms is suggested by the protoplasmic inclusions; however, the majority of Foraminifera thrive upon bacteria and the products of bacterial decomposition of plant and animal tissue provided other conditions are favorable.

The life span of recent species based upon statistical data of growth stages in populations range from a few weeks to more than two years and it seems probable that certain of the larger Foraminifera survived for considerably longer. Populations vary from a few to many thousands of individuals per square foot, and the presence of vast numbers of tests of a single species in a sample may or may not suggest sorting.

We need to know more concerning the amount of test erosion and solution that takes place when Foraminifera pass through the digestive tract of larger organisms. Broken and not otherwise eroded tests are abundant in certain samples. Arthropods often feed upon these Protozoa by crushing the tests, and skates, molluscs and other organisms that dig and burrow cause mechanical pressure sufficient to fracture tests that may have been previously weakened by solution resulting from age or reproductive activities, since a part of the shell substance as well as all of the protoplasm is used to produce gametes or juveniles as the case may be.

Although the Foraminifera have been more effectively catalogued than any other group of marine organisms, and the literature is most voluminous, only a few workers have contributed appreciably to our knowledge of the biology of the group and their life activities in relation to measurable ecological conditions in the sea.7/ The group is difficult to work with and cooperation is necessary in collecting ecological data, but the knowledge to be gained when applied to petroleum geology should justify the cost and effort.

Many petroleum geologists have recognized and written concerning the need for further studies on the biology of the Foraminifera, but unfortunately the work is not a widely recognized field of research, and it is difficult to interest Universities, Marine Biological, or Oceanographic Stations although many of these institutions conduct work on marine sediments and the taxonomy of the Foraminifera. If the maximum use of the Foraminifera as guides in Paleoecology and Stratigraphy is to be realized while the work is of greatest value, concerted efforts to stimulate research on ecological studies of the Foraminifera at one or more suitable institutions should be made.

---

7/ Myers, E. H., Life activities of the Foraminifera in relation to marine biology, Proc. Amer. Phil. Soc. vol. 86, no. 3, 1943.

# REEFS AND OTHER BIOHERMS

by

Harry S. Ladd[8/]
U. S. Geological Survey

In studying elevated reefs or reeflike structures it is important to know if the structure rose above the sea floor to a level at or very near the surface of the sea. Structures that do this are wave-resisting and studies of those in existence today show that locally they have a great influence on the circulation, temperature and salinity of the sea and on the kind and amount of the sediments deposited nearby. Structures of this kind are true reefs and they should be differentiated from all other types of organic deposits that are formed below the zone of wave action.

There has been much discussion about the use of the terms "reef" and "coral reef" in geology. E. R. Cumings and R. R. Shrock pointed out some years ago (Bull. Geol. Soc. Amer., vol. 39, p. 599, 1928) that both terms were somewhat misleading and they suggested the term bioherm as a substitute. In 1931 in his Presidential Address to the Paleontological Society entitled "Reefs or Bioherms?" Cumings (Bull. Geol. Soc. Amer., vol. 43, pp. 331-352, 1932) discussed the difficulties of terminology in some detail, gave a definition of the term bioherm and proposed a new one, biostrome. According to these definitions the most important features of "reefs" are organic constitution, shape, and the presence or absence of bedding. Thus a bioherm is a reeflike, moundlike, lenslike or otherwise circumscribed structure of strictly organic origin embedded in rocks of a different lithology. A biostrome is a bedded structure built mainly by sedentary organisms but not swelling into moundlike or lenslike form. Both of these terms are very useful particularly as applied to elevated "reefs" and they have been used by many workers. There seems to be ample justification, however, for retaining the word reef for a wave-resisting bioherm.

The term reef has two separate usages in many English-speaking countries, both being cited in standard dictionaries: it is used by prospectors and miners for a vein or lode and it is used by seamen for any chain of rocks or ridge of sand sufficiently close to the surface of the water to be a menace to navigation. Into this latter category fall the fringing reefs, barrier reefs, reef patches and atolls of the coral seas. Many lie so close to sea level that they are exposed or awash at low tide and even at high tide the waves break over them. Structures of this type have a far more profound effect on the ecological environment than do others that, though they may lie in comparatively shallow water, are below the main zone of wave action. It is suggested, therefore,

---

8/ Published with the permission of the Director, Geol. Survey, U. S. Dept. Interior.

that in studying elevated organic structures the term reef be applied only to those that show clearly by geologic or biologic evidence that they were wave-resisting structures. Students of existing reefs have long recognized that the wave-resisting qualities of the reefs of the tropical seas are due primarily to the presence of cementing algae of fairly recent types, geologically speaking. For this reason analogies between existing reefs and Paleozoic bioherms should be made with great caution.

In a number of papers that have appeared since Cumings and Shrock defined their bioherms and biostromes a great variety of organic structures have been described. C. L. Fenton and M. A. Fenton adopted the new terms in a paper dealing with algal structures in the Pre-Cambrian Belt series of Montana (Bull. Geol. Soc. Amer., vol. 44, pp. 1135-1142, 1933; abstract, same volume p. 212). The bioherms described are small structures, the larger one of the two having a width of 35 feet and an observed height of 25 feet. They are referred to as "reefs or bioherms" though there appears to be no evidence to indicate that they formed in very shallow water. In this paper the terms reef and bioherm appear to be synonomous.

In R. R. Shrock's detailed descriptions of the Wisconsin Silurian bioherms (Bull. Geol. Soc. Amer., vol. 50, pp. 529-562, 1939) the structures are referred to parenthetically as organic reefs but they are not compared directly to existing surface reefs. It is stated that the bioherms appear to have accumulated in fairly shallow water and Shrock believes that they stood as low moundsafew feet to a few tens of feet above the surrounding bottoms. To support his contention that the waters were fairly shallow, Shrock cites the occurrence of mud cracks, ripple marks and cross-lamination; the occurrence of coquina-like accumulations is interpreted as evidence of vigorous wave and current action. The largest of the mounds may have been as much as 100 feet thick.

In a report on the Mississippian formations of the Sacramento Mountains of New Mexico, R. L. Loudon and A. L. Bowsher describe some large and spectacular structures that occur in the Alamogordo member of the Lake Valley formation (Bull. Amer. Assoc. Petrol. Geol., vol. 25, pp. 2107-2160, 1941). In their descriptions of these markedly unfossiliferous structures the authors consistently refer to them as bioherms, wisely avoiding the use of the word reef. The largest bioherms are as much as 200 feet thick and nearly a mile across the base but all are said to be distinct, abrupt and conspicuous structures. In a diagram showing typical structure (fig. 10) and in a restoration of the sea bottom (fig. 15) they are indeed abrupt, the diameter of each bioherm being only two or three times its thickness.

Recognizing the problem of compaction of sediments, the authors give some consideration to the possibility that the hard bioherm facies may have accumulated contemporaneously with the surrounding sediments at approximately the same level. They offer evidence which they believe at least partly refutes this possibility and conclude that the main bioherm structures rose as distinct knobs from the sea floor.

No definite statements are made indicating the relation of the tops of the bioherms to sea level, though references to "lagoonal areas" and "lagoonal facies" would seem to imply that some of the bioherms were built up close to sea level. This implication is given support by figure 15, an artist's illustration of the appearance of the sea bottom in the Marble Canyon area in Mississippian time. In this diagrammatic representation some of the knob-like bioherms rise practically to the surface of the sea. Bioherms such as these would be wave-resisting structures comparable to the reef patches of existing seas. Actually, however, no geological or biological evidence to support this tide-water conception is presented.

The Laudon-Bowsher paper has recently been cited by Donald Parkinson (Proc. Geol. Soc. London, No. 1390, pp. 14-16, 1943) who states that the Lower Carboniferous "reef-knolls" of the Clitheroe district in Lancashire closely resemble the Mississippian bioherms of New Mexico.

J. Harlan Johnson published a paper on the Permian lime-secreting algae from the Guadalupe Mountains in New Mexico (Bull. Geol. Soc. Amer., vol. 53, pp. 195-226, 1942). Following a study of the structures and relationships of the algae themselves and the organisms associated with them he attempted to reconstruct the ecological conditions which appeared to exist at the time the deposits were formed. This attempt is not convincing because of the lack of supporting data. In the section on "Ecology" at the end of the paper it is stated that "Ecologically all the material studied came from either some portion of the reef facies of these deposits or from that portion of the lagoonal facies adjoining the reef", but no description of the reef rock as it occurs in the field is given. Four ecological facies are recognized but no data are given as to their occurrence and distribution in the field nor are any of the described species assigned to any particular facies. Only in connection with the problematical pisolite masses is an environment suggested. No convincing evidence is presented to indicate that the Permian algal deposits are analagous to modern reefs though such comparison is made and an idealized profile across a reef showing various ecological forms is included. The divisions recognized in this profile are not tied to the localities from which the algae were collected.

In Philip B. King's comprehensive report of the Permian of west Texas and southeastern New Mexico (Bull. Amer. Assoc. Petrol. Geol., vol. 26, pp. 535-763, 1942) reefs play a very important part in the interpretation of the geological history of the area. The most important reefs are those in the Guadalupe series, the Goat Seep and Capitan limestones. These reefs are admittedly not coral reefs though King believes that they resembled the modern reefs of the tropical seas in many ways. He points out that the modern reefs and the Permian structures are thick accumulations of limestone, parts of which are elongate reef masses constructed by organisms, that the structures slope abruptly seaward into deep water and merge landward into horizontal lagoonal deposits. The Permian structures, according to King, developed on slopes of tectonic origin in warm, shallow, agitated waters and at times actually formed barriers that shut off large areas from free access to the sea.

Much evidence involving regional relations is presented in support of the reef interpretation. In recognizing the structures as reefs, King points to the massive character of the limestone, the steep dips that are thought to be original dips, the narrow transverse extent of the structures and the rapid transition into other deposits.

King states that reefs were built up with the aid of such lime-secreting organisms as sponges, crinoids and algae. The algae, presumably, are the important members of this group. The greater part of the Capitan carries a facies characterized by sponges and algae. This is considered to be a true reef-building assemblage. No quantitative estimates of the importance of either group is given but it is stated that the sponges were abundant and of many types. For detailed information on the algae King refers to Johnson (Ecologic distribution of lime-secreting algae in the Permian Carlsbad Reef, Guadalupe Mountains, New Mexico, abstract, Bull. Geol. Soc. Amer., vol. 50, p. 1915, 1939 and Permian lime-secreting algae from the Guadalupe Mountains, New Mexico, Bull. Geol. Soc. Amer., vol. 53, pp. 216-217, 1942) but as noted earlier, Johnson gives no data as to the distribution of the several ecological facies nor, indeed, any evidence to show that the algae actually formed reefs.

Pending the presentation of additional biological evidence demonstrating clearly that these exceedingly thick Permian structures were actually near-surface reefs built by shallow-water organisms, it might be better to refer to them as bioherms and to avoid direct comparisons with the existing reefs of the tropical seas.

A. S. Warthin and G. A. Cooper in a recent paper on the Devonian Traverse rocks of the Thunder Bay region in Michigan (Bull. Amer. Assoc. Petrol. Geol., vol. 27, pp. 571-595, 1943) make brief references to the bioherms and biostromes found in several of the Middle Devonian formations. These organic structures are properly designated except for the suggestion (p. 586) that an aggregation of bioherms in the upper part of the Alpine limestone is probably best called a reef.

J. Harlan Johnson has recently described some algal reefs in the Cretaceous Austin chalk of the Terlingua district in Texas (Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 123-124, 1944). The reefs are small but well developed. Johnson states that the algae appear to belong to sediment-binding types. Thin sections showed the rocks to consist of "a mat of fine algal filaments enclosing some foraminifera, tiny fragments of marcasite or pyrite and silt particles." He says that the algae grew in shallow water and that "gradually masses of impure calcareous material accumulated eventually to form the nodules, lenses and reefs."

# CALIFORNIA FOSSIL FISH SCALE ASSEMBLAGES

by

Lore Rose David
Richfield Oil Corp. - Long Beach, Calif.

Studies of fossil fish scales in the Tertiary deposits of California were continued along the same lines as indicated previously (Third report of the Committee on Marine Ecology as Related to Paleontology, pp. 31-32, 1943). The existence of certain assemblages in sediments of the same age over large areas has been substantiated. Many new types and assemblages were found and "flood" zones of certain types were reliably established as usable markers in local areas.

The known Tertiary types of fish scale assemblages may be reviewed as follows:

In the Pliocene fish scales are rare and in general poorly preserved. Characteristic types of Pliocene shallow water (Etchegoin formation of San Joaquin Valley, Pliocene Santa Maria Basin) are: Several undetermined species of flat fishes (Heterosomata), Cynoscion, Syngnathus, a smelt related to Atherinopsis. The Pliocene often shows a deep bathyal or abyssal fauna (Middle Pico near Oxnard, Lower Pliocene Hasley Canyon, Ventura County, Repetto Los Angeles Basin) with various rattails (Macrouridae), deep sea Gadidae, Bathygadus, Merluccius and others.

The deep neritic fish faunas characteristic for the Upper Miocene (Mohnian) were described in an earlier report.

The Middle Miocene is indicated by warmer and shallower water. A round herring, related to Etrumeus, is the most characteristic form. In regions where the Middle Miocene sea was shallower this form is found higher in the section (Luisian stage Caliente Range of Santa Maria Basin) than in other areas where it characterizes the Relizian. Large Sciaenidae, porgyfishes, a smelt related to Atherina and other undetermined types are commonly found. Several species of shads (Ganolytes), a genus commonly found in the Mohnian, are very abundant.

The Lower Miocene deep water faunas were previously described. Lower Miocene to Oligocene assemblages of shallower water were found to be well represented in the Santa Maria, Santa Barbara Basins (Vaqueros, Lower Rincon formation). Serranid fishes become more predominant with ?Mycteroperca being quite abundant in places. A large scale probably related to the salmonoid Leucichthys is also abundant in places. The Clupeoidea are represented by a medium sized undetermined scale, together with Etringus sp., which is the common round herring of the Upper and Middle Miocene, the latter represented by a different species. No Ganolytes are present. Sparoidea are common.

The characteristic Upper Eocene deep bathyal fauna was described from the San Joaquin Valley previously. It is present also in the Upper Eocene of the Coast Ranges, (Santa Barbara - San Marcus Area).

At the top of the Eocene section studied in the Simi Valley, (Llajas formation) species equivalent to the Lower Kreyenhagen were present. Underlying these species was observed a large smelt-like scale which may mark the top of the Middle Eocene approximately equivalent to the Domengine. An abundant fish fauna was present in the Middle Eocene (Domengine), with small scales of coastal types predominant: A serranid fish, probably related to Paralabrax, is most abundant together with the small scales of a sparoid fish, Kreyenhagenia sp. Scales of certain Iniomi and occasionally Berycomorphi are also found, but only very small scales of a genus related to Chlorophthalmus are common. Towards the basal strata containing this fauna Iniomi increase in number and size, and the coastal forms disappear. The sea in the Middle Eocene of this area may have been approximately 100 fathoms deep.

The fish scale assemblages very often show an intermingling of forms of different ecological environments, as for instance in the above-mentioned Middle Eocene assemblage. Deposition on or near steep slopes of the continental shelf or at the bottom of relatively deep arms or embayments of the sea are the best explanation for this condition. Statistical evaluation of the relative abundance and the preservation of the various types of scales furnish important clues as to the determination of the conditions prevalent during the deposition of the sediments.

# RELATIONS OF SALINITY AND TEMPERATURE TO DISTRIBUTIONS OF THE MARINE FISHES OF TEXAS

by

Gordon Gunter
Texas Game, Fish and Oyster Commission

(Mr. Gunter has just completed a report of an ecological study of Texas marine fishes, which will be published later. The author's summary of his work is given below and is followed by comments on points of interest to paleontologists).

1. The distribution of marine fishes in relation to salinity of the water is little known. Such information is a necessary part of fishery biology and is fundamentally related to problems of physiology, ecology, zoogeography and evolution. The chief purpose of this study was to get facts on the distributional relationships of Texas coastal fishes to salinity, but certain effects of temperature on fishes were also studied and life history notes were made.

2. Texas has a double coastline of barrier islands and mainland shore. The coastal lagoon between connects with the Gulf of Mexico by few narrow channels through the islands. Landward from the lagoon lie more recently formed back bays into which the rivers flow. The area studied included Copano Bay, a back bay, Aransas Bay, a part of the lagoon, and the adjacent part of the Gulf of Mexico, extending five miles offshore and five miles south on the Gulf beach from Aransas Pass. Here in a running distance of forty nautical miles is a salinity gradient ranging from almost fresh water at upper Copano Bay to normal sea water in the open Gulf. Rainfall is low, drainage is slow, and tidal exchange is small, so that the salinity gradient is relatively stable. The bays have a marginal area of shallow flats composed of sand or mud, with deposits of oyster shell and covered in many places with growths of algae and grass. The deeper part of the bays have mud bottoms, except for the oyster "reefs" which were not studied. The Gulf beach is relatively barren sand and the offshore bottoms are mud. The deepest part of Copano Bay is 8 feet, the deepest part of Aransas Bay is 13 feet, and the deepest offshore station in the Gulf was 60 feet.

3. Fishes were caught at regular stations visited one a month when possible. Work extended from March 1941 to November 1942, but was most intensive from June 1941 to August 1942, inclusive. Small fish were caught on the bay flats and Gulf beach in minnow seines. Large fish were caught on the bay flats in trammel nets and on the Gulf beach by beach seines. Small and medium-size fish were taken in the offshore waters of the bays and Gulf with shrimp trawls. There were ten minnow seine stations in the bays and two on the Gulf beach. There were eight trammel net stations in the bays and two large seine stations on the Gulf beach. There were seven trawl stations in the bays and two in the Gulf of Mexico.

4. At stations all fishes were counted by species and up to fifty of each species were measured in total length. The gonadal condition and the stomach contents of some of the larger fishes were noted. Water temperatures were taken and salinity was determined by hydrometers. Average salinities in parts per thousand in Copano Bay, Aransas Bay and the Gulf of Mexico were 9.1, 20.5 and 31.5 respectively. The temperature at the stations varied from 7.8 to 34.0° C. In the text the monthly catch records, the seasonal movements, various life history notes and distributions of the fish at various salinities are discussed.

5. One hundred and twenty species and 78,265 specimens were caught. Fourteen thousand seven hundred and ninety-six fishes were taken in the Gulf and 63,469 were taken in the bays. Seventy-three species made up less than 1.5 per cent of the catch. Fourteen species were taken over a thousand times each. The croaker, Micropogon undulatus, the bay anchovy, Anchoa mitchilli diaphana, the silverside, Menidia beryllina peninsulae, the sheephead minnow, Cyprinodon variegatus variegatus, and the mullet, Mugil cephalus, were taken over 5,000 times each and the first three species made up almost half the catch, being caught 36,956 times. It was estimated that the anchovy, A. mitchilli diaphana, the menhaden, Brevoortia sp., the mullet, M. cephalus, and the croaker, M. undulatus, have the largest species masses of any fishes on the Texas Coast. Fishes of the families Sciaenidae, Engraulidae, Atherinidae, Cyprinodontidae, Mugilidae and Clupeidae were most often caught in that order.

6. Trawl catches of fishes compared to catches made in a previous study in Louisiana were similar. The croaker, M. undulatus, and the anchovy, A. mitchilli diaphana, were very abundant in both places. Two catfishes, Bagre marina, and Galeichthys felis, the threadfin, Polydactylus octonemus, and the sand trout, Cynoscion nothus, were relatively more abundant in Texas waters, while the cutlass fish, Trichiurus lepturus, the star drum Stellifer lanceolatus, and the banded drum, Larimus fasciatus, were much less abundant on the Texas Coast. Several specimens of the gizzard shad, Dorosoma cepedianum, the rough scad, Trachurus lathami, the pinfish, Lagodon rhomboides, the pigfish, Orthopristes chrysopterus, and the white mullet, Mugil curema, were caught in trawls in Texas, but not in Louisiana. In each place a few rarely caught species were taken that were not taken in the other.

7. The most numerous fishes on the bay flats of the Texas coast were the silverside, M. beryllina peninsulae, the cyprinodontid, C. variegatus variegatus, the anchovy, A. mitchilli diaphana, the mullet, M. cephalus, and the cyprinodontid, Fundulus similis. The silverside and the cyprinodontids are rarely caught in the Gulf or in deep water. They are typical of bay flats. The most abundant fishes in the deeper waters of the bay were the croaker, M. undulatus, the anchovy, A. mitchilli diaphana, the catfish, G. felis, and the sand trout, Cynoscion arenarius. On the Gulf beach the most abundant fishes were the sardine, Harengula macropthalma, the anchovies, A. mitchilli diaphana and A. hepsetus, the threadfin, P. octonemus, and the pompano, Trachinotus carolinus. In the deeper Gulf waters the most abundant fishes were the sand trout, Cynoscion nothus, the croaker, M. undulatus, the threadfin P. octonemus, the catfish, G. felis, and the moonfish, Vomer setapinnis.

The larger fishes most commonly taken on the bay flats were the mullet, M. cephalus, the speckled trout Cynoscion nebulosus, and the redfish, Sciaenops ocellata. The most common large fishes taken on the Gulf beach were the spot, Leiostomus xanthurus, the mullet, M. cephalus, and the stingaree, Dasyatis sabina.

8. During the fall most fishes in the bays began to move towards the Gulf. The absence of a species was generally first noticed in Copano Bay, later becoming noticeable in Aransas Bay. Many species were taken in the Gulf only in the winter. Several other species apparently left the area entirely. In the spring and summer the fishes returned to the bays. There was a counter movement of a few species, that were taken in the bays only in the winter. Seasonal movement of fishes is primarily a result of temperature change, the influence of salinity being minor.

9. A mild cold spell in January 1942 killed several fishes. The most numerous animals killed were the two fishes A. mitchilli diaphana and M. beryllina peninsulae and the peneid shrimp, Penaeus setiferus. The effect of the cold was more severe in Copano Bay than in Aransas Bay. No fishes were found killed by cold in the Gulf of Mexico.

10. The spring of the year is the time of greatest spawning activity among the marine animals of the Texas Coast. Most fishes spawn at times of rising or warm temperatures, but several numerically important species spawn at the season of falling or low temperatures. Several of the winter migrants from the bays go to the shallow Gulf to spawn.

11. Several of the most numerous species spawn at medium or low salinities in the bays, while many other species spawn in the saltier water of the Gulf of Mexico.

12. The bays are not refuges for spent races. They may be more correctly characterized as nursery grounds for many coastal fishes and crustacea, but they are not nursery grounds alone; many coastal fishes spend most of their lives in the bays.

13. The fauna of brackish water is marine and the fresh water element in it is negligible. A great many marine animals can withstand salinity dilution, but very few fresh water animals can withstand increase in salinity.

14. Many fishes were taken only at the highest salinities and several species taken at medium salinities were not taken at the lower salinities. In contrast, practically all fishes taken at the very lowest salinities were also taken at the higher salinities. Practically every fish living at lower salinities, except for four fresh water fishes, can also live in sea water.

15. There is a relationship between salinity of the water and the size of fishes in that the smaller specimens were usually found in the freshest water and the largest were usually found in the saltier water. Many examples

of this are shown in the paper, but the situation is not simple and there are exceptions to it. In general the size of fishes increased as the distance covered by the salinity gradient was traversed from lower to higher salinities.

## POINTS OF INTEREST TO PALEONTOLOGISTS

The area studied covers the marginal region where the transition from sea water to fresh water takes place and is therefore of more interest to students of coastal geology than to those who are studying open sea deposits. The fauna of brackish water, including that which is very nearly fresh, is marine and the fresh water components are rare. This condition is clearly shown in the present paper as well as by other studies cited in the bibliography. Many marine fishes cannot tolerate salinities falling much below that of the open sea but as a whole they tolerate salinity dilution much better than fresh water fishes tolerate a rise in salinity. For this reason the populations of fishes and crustacea in the back bays where the water is very nearly fresh are always found to be predominantly or completely marine. This is a fundamental condition which seems to be unvarying. There is every reason to believe that the same situation held in the past. For the paleontologist it means that assemblages of fossil animals from coastal areas thought to be marine, did not necessarily live in a marine habitat. Salinity of the water may have been very low. The number of marine fishes that invade fresh water is much larger than the number of fresh water fishes that invade the sea. Homossasa Springs, Florida may be cited as an example of an area where large numbers of marine fishes are commonly taken in fresh water. For these reasons the finding of a fossil marine fish is not a sure indication that the beds containing it were laid down in salt water or that the fish was living in salt water.

There is a general direct correlation between the size of many species of fishes and the increase in salinity as the salinity gradient is traversed from fresh water towards salt water. The same appears to hold true for various invertebrates, but the supporting data have not been presented. Though it is true that the bay areas are largely nursery grounds from which the fishes migrate to deeper water as they grow older, the correlation between size and salinity is believed to be a true one. The situation seems to hold for all bay areas on this coast and probably holds for bay areas in other parts of the world. For the paleontologist it means that if he finds small fossils of a fish in one locality and finds larger sizes of fossils of the same species at the same horizon a few miles away, he has some grounds for assuming that he is following a rise in the salinity gradient.

In this work an attempt was made to gather information on the relative abundance in numbers as well as what is called relative species masses. It seems that knowledge of the relative species mass of animals in any given place or life aggregation is necessary for an understanding of animal communities or associations. The same thing should hold true in the thinking of the paleontologist concerned with the death aggregates or assemblages which he finds. Some animals are extremely uncommon in a given environment

and some of them apparently are never common anywhere. Others may be overwhelmingly abundant and therefore much more important in animal communities and associations than the species with less numerous individuals. In this work it was found that two species of plankton feeders had the greatest species mass of any fishes on the Texas coast. A third extremely abundant fish, the mullet, feeds on material sucked up from the bottom, of which the food component is largely diatoms and bacteria. A fourth very abundant fish is an omnivorous bottom feeder. It is significant that three of the four species with greatest species mass on this coast feed on diatoms and other plankton. In other words they feed at the base of the food pyramid where the supply of food is greatest. It is to be expected that fishes with such feeding habits would be more abundant than other species and probably similar studies in practically all other marine habitats would show the same situation. By the same token it is fairly reasonable to assume that the same situation held true in the fish assemblages of the past. Other things being equal abundant species are more likely to become fossilized than the rare or uncommon fishes. However, uncommon fishes with hard parts would quite likely leave better records than the soft fishes, although the latter might be much more abundant. It is quite possible that the ancient seas swarmed with large numbers of soft-boned, soft-rayed, plankton-eating fishes which left little record, so that the paleontologist has been chiefly concerned with the armored species or those containing hard parts. Although the paleontologist may never find it possible to prove or disprove the correctness of this, such possibilities should be held in mind when the ecology of fossil fishes is being considered.

Comparisons between the populations of fishes taken in trawls on the Louisiana coast and those taken on the Texas coast, some four hundred miles away, show more similarities than differences. In general the same several species are the most abundant in both places and hold the same general rank in abundance. In other words fish populations in comparable environments, rather wide distances apart, were found to have much the same composition so far as species and relative abundance of the same species were concerned.

This work shows that the populations of fishes near the shore were quite different from those in deeper water and although many species inhabited both places, several species, some of them extremely abundant, did not leave the marginal area of shallow flats along the shore. It also showed that several species which could tolerate very high salinities were not found on the shore of the open sea but only in the bays, apparently because of lack of vegetational cover on the Gulf beach. Here, in contrast to the similarity of populations from trawl catches in Louisiana and Texas in similar environments, although rather larger distances apart, we have a contrast in the population of fishes within short distances in the same body of water. There was as much or more change from a depth of 1 or 2 to 6 or 10 feet than there was in a distance of several hundred miles along the same coast at the same depths.

This work shows that in even rather mild cold, numbers of fishes and crustacea are killed during the winter in the shallow coastal waters of Texas. At times death of fishes in this area due to cold takes on

catastrophic proportions, as shown in papers cited in previous reports of this Committee. Other things being equal fossilization is probably much more likely to take place during the winter than during the summer, when bacterial action is so much more rapid. Seasonal changes in plant and animal populations of all kinds doubtless took place in the past just as they do today, but it must be admitted that such facts may be of little use to the paleontologist whose difficulties in ascertaining the general climatic conditions over a large number of years are great or insurmountable.

- - - - -

LIST OF REPORTS IN THIS SERIES *

No. 1 - Report of Subcommittee on the Ecology of Marine Organisms, 1940-41. 1st edition, Nov. 1941; 2nd ed., July 1944. 51 pages.

No. 2 - Report of the Committee on Marine Ecology as Related to Paleontology, 1941-42. Dec. 1942. 58 pages.

No. 3 - Report of the Committee on Marine Ecology as Related to Paleontology, 1942-43. Dec. 1943. 32 pages.

No. 4 - Report of the Committee on Marine Ecology as Related to Paleontology, 1943-44. Oct. 1944. 37 pages.

* (Price - $0.50 each, except one free copy to:
Committee Members, Contributors to the reports,
or Libraries of Educational Institutions -
the last on request).